METS III

MIDDLE EAST TURBOMACHINERY SYMPOSIUM

15-18 FEBRUARY, 2015, DOHA, QATAR

Low lift Dry Gas Seals in high vapor pressure, flashing hydrocarbon pump applications

Authors: Patrick Shaw, EagleBurgmann
Kent Prichard, EagleBurgmann

EagleBurgmann®

TEXAS A&M UNIVERSITY

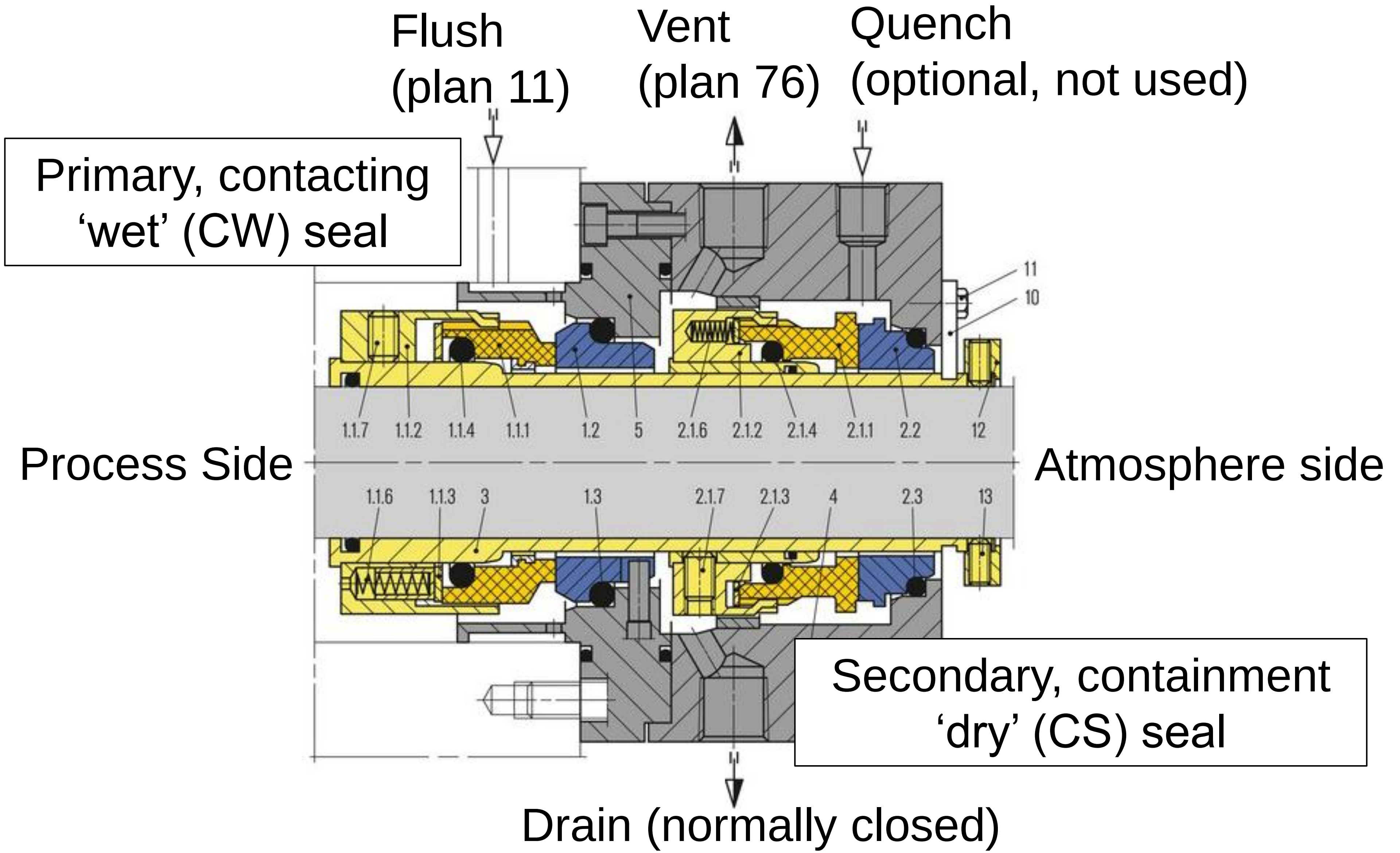
TEES TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

Problem

Ethane pumps with process lubricated; ‘liquid (wet)’ 2CW-CS, plan 11, 76, seals suffered a high frequency of seal failures from initial commissioning in November 2009

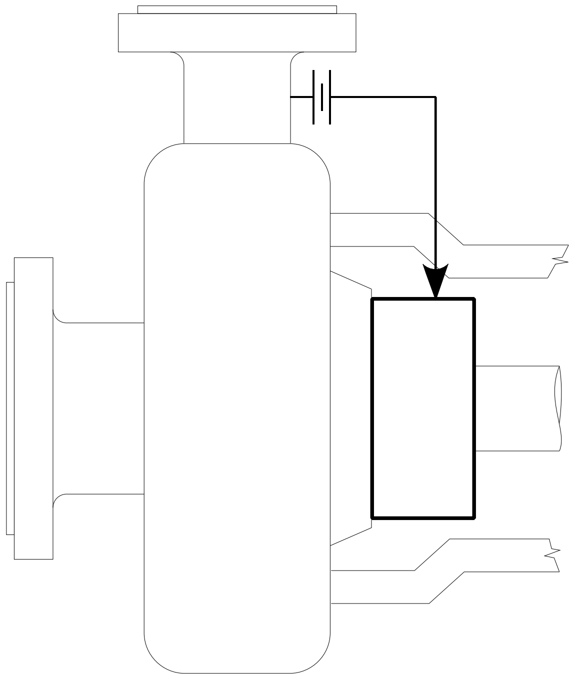
- 2 fractionator units each with 2 ethane export pumps
- 12 stage, BB3 axially split
  - 5.7MW absorbed at BEP
- suction pressure 40.7-50.3 barg
- suction temperature 12.8-18.9 °C
- 3570 rpm, 89mm shaft size
  - Shaft speed 16.6 m/s, p.v 677-837 bar.m/s
    - 81-96% of API682 scope
- Typical flow range 277–345 m^3/h
  - 136 / 331 / 408 m^3/h (MCSF / BEP / EOC)

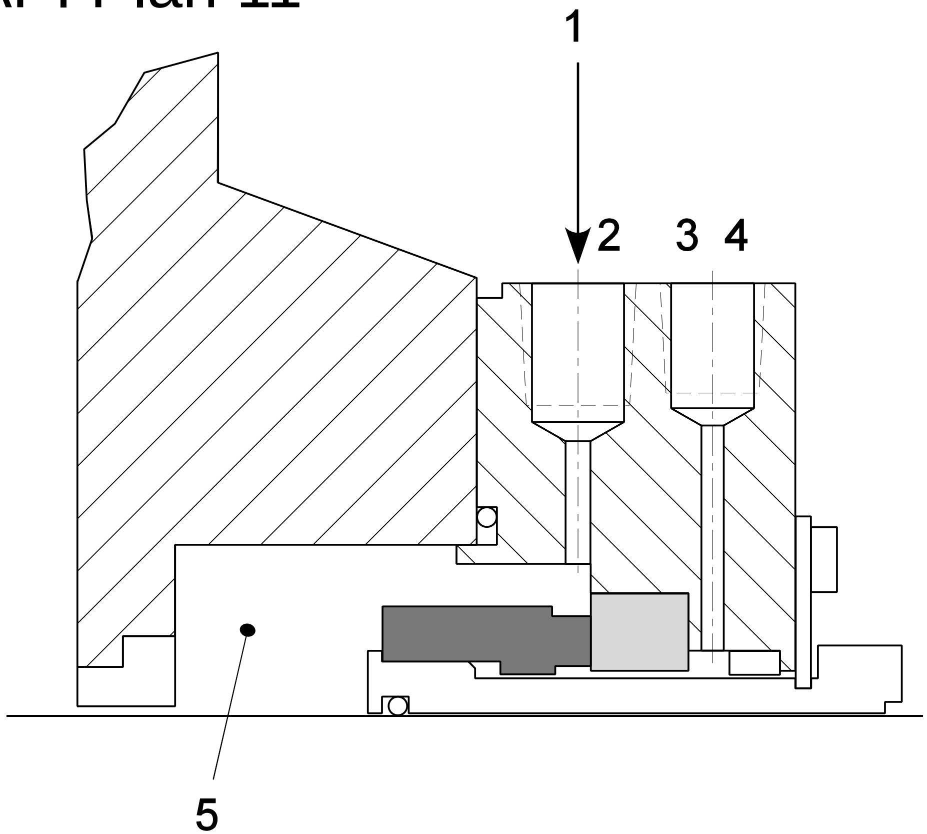
BB3 axially split, 12 stage pump, 6 + 6 opposed impellers



<u>'Generic' Type A, Arrangement 2 seal, 2CW-CS</u>

Flush - API Plan 11





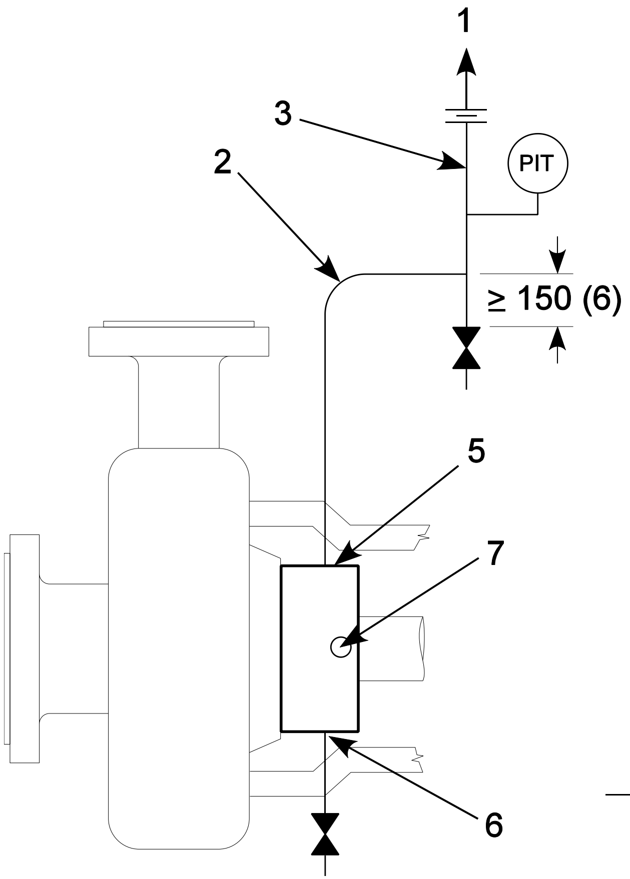
recirculation from a high pressure region of the pump through a flow control orifice to the seal

- Primarily: to remove seal generated heat
- Optionally: increase seal chamber pressure (special measure)

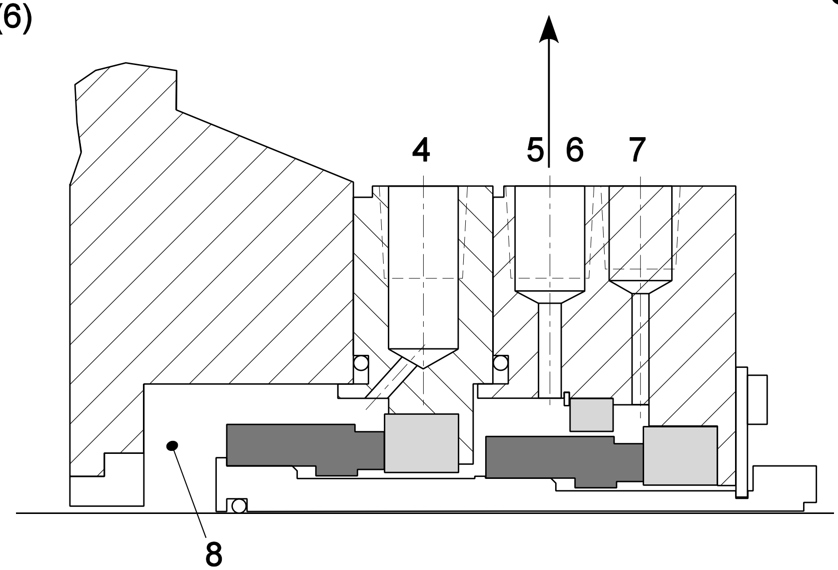
Key

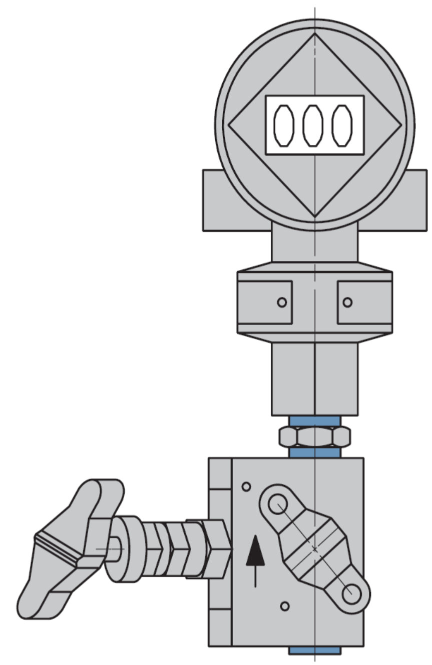
1	to vapour collection system
2	tube
3	pipe
4	flush (F)
5	containment seal vent (CSV)
6	containment seal drain (CSD), closed
7	gas buffer inlet (GBI)
8	seal chamber
PIT	pressure transmitter with local indicator

Vent - API Plan 76



Vent to vapour collection system via leakage detection / monitoring





Engineering phase

The process condition at suction did not satisfy API682 requirement of a minimum 30% pressure or 20K temperature vapour margin for process at seal:

Vapour margin at suction conditions:

- Pressure margin approx. 17% (40,7 / 34 barg)
- Temperature margin approx. 5K

Mitigation:

- Seal design featured a special throat bushing to permit plan 11 flow to ensure pressure margin in seal chamber
- Discussion with oem to ensure API requirement would be met

Commissioning phase

During commissioning there were numerous process incidents resulting in loss of suction vapour margin

- Process flow
- Process heat exchanger

Once resolved problems continued to occur

- Cavitation

Post commissioning

Plan 11 - three machine build / installation issues were discovered:

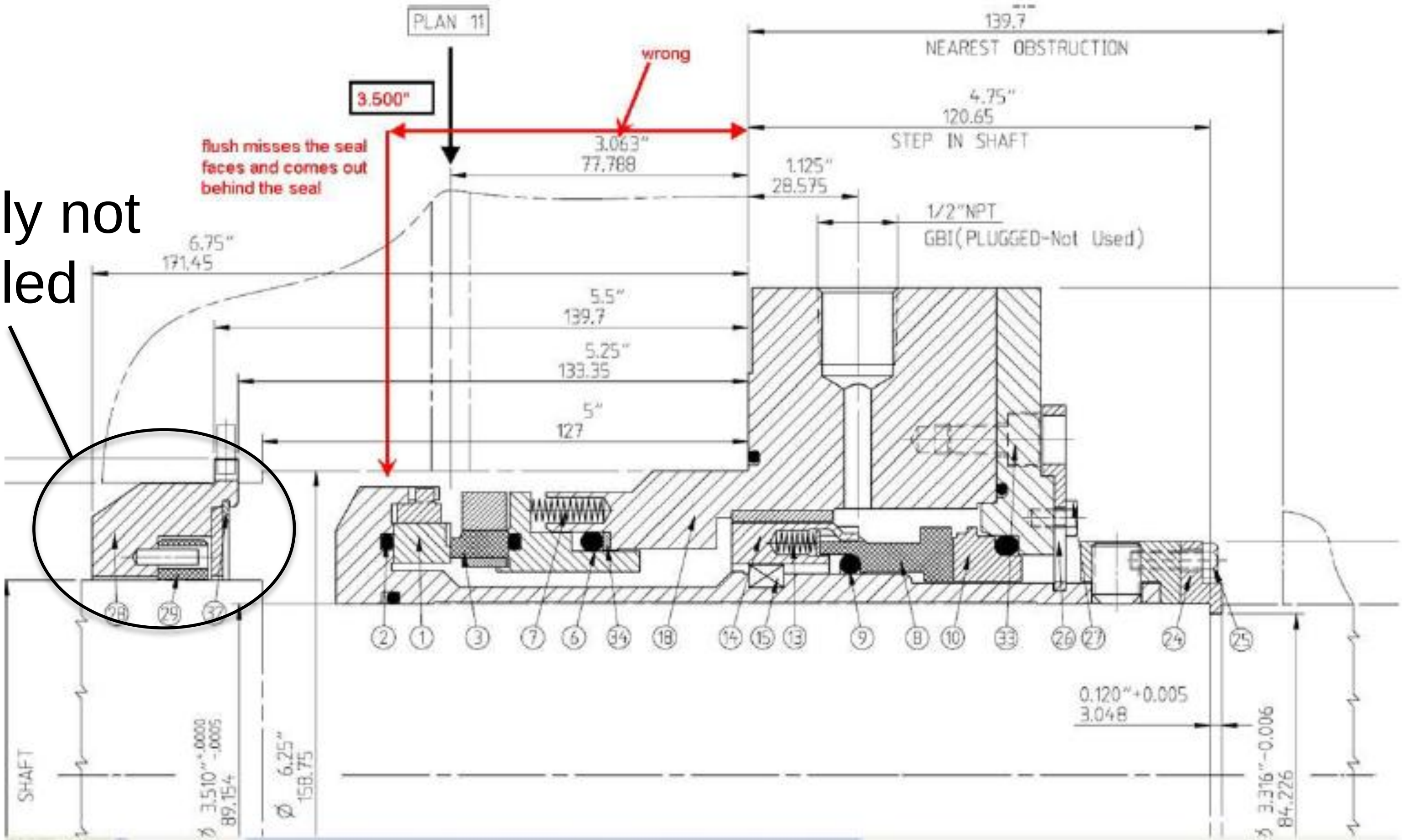
1. special floating throat bushing had not been installed
   - no increase in vapour pressure margin at seal

2. minimum size 3mm dia flow orifice installed in plan 11
   - flow rate marginal for removing seal heat
   - insufficient to significantly improve seal vapour margin if throat bushing were installed

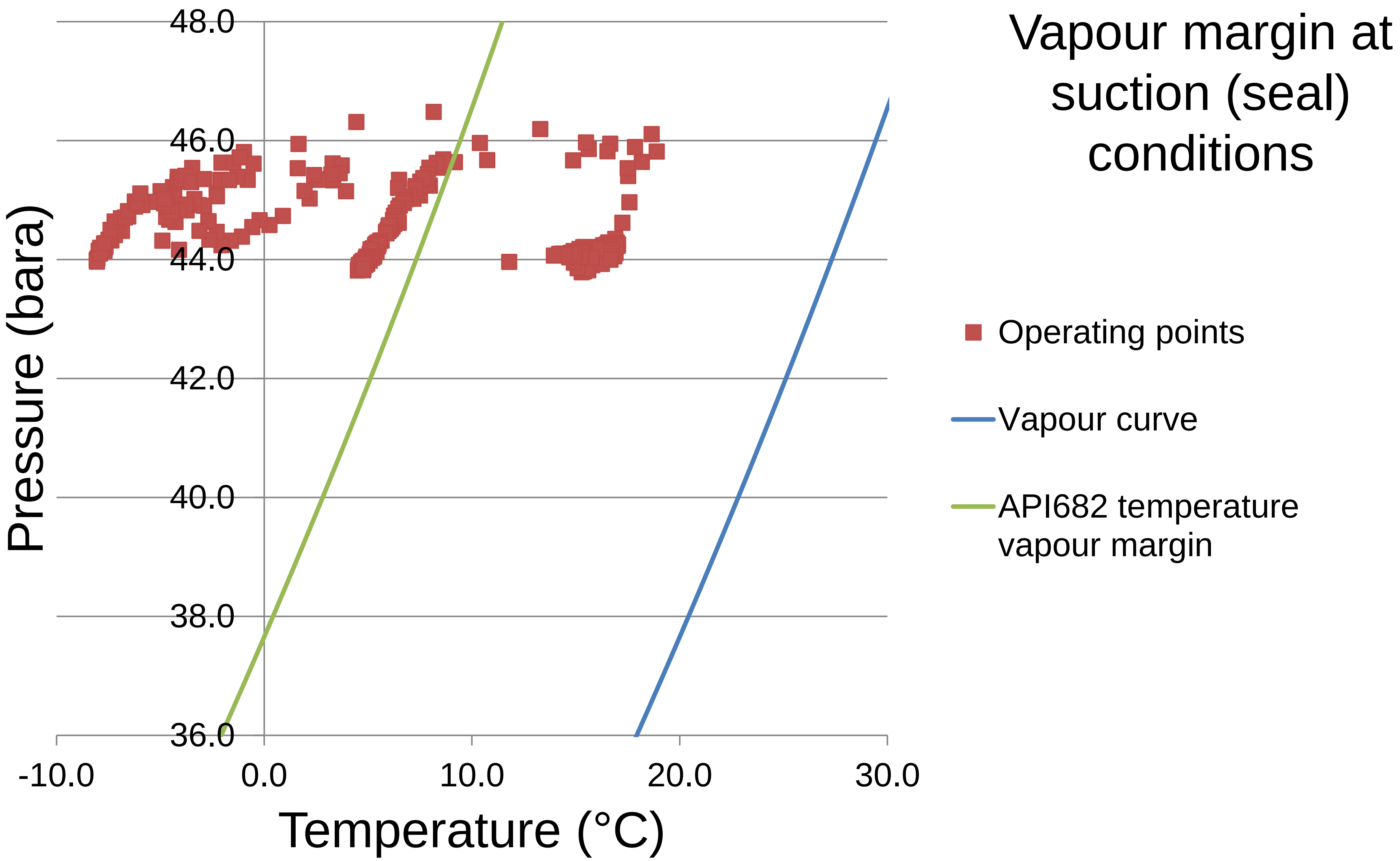
3. connection in seal chamber incorrectly positioned
   - misaligned to seal faces; seal cooling not optimal

3mm FO limits flow rate

Initially not installed



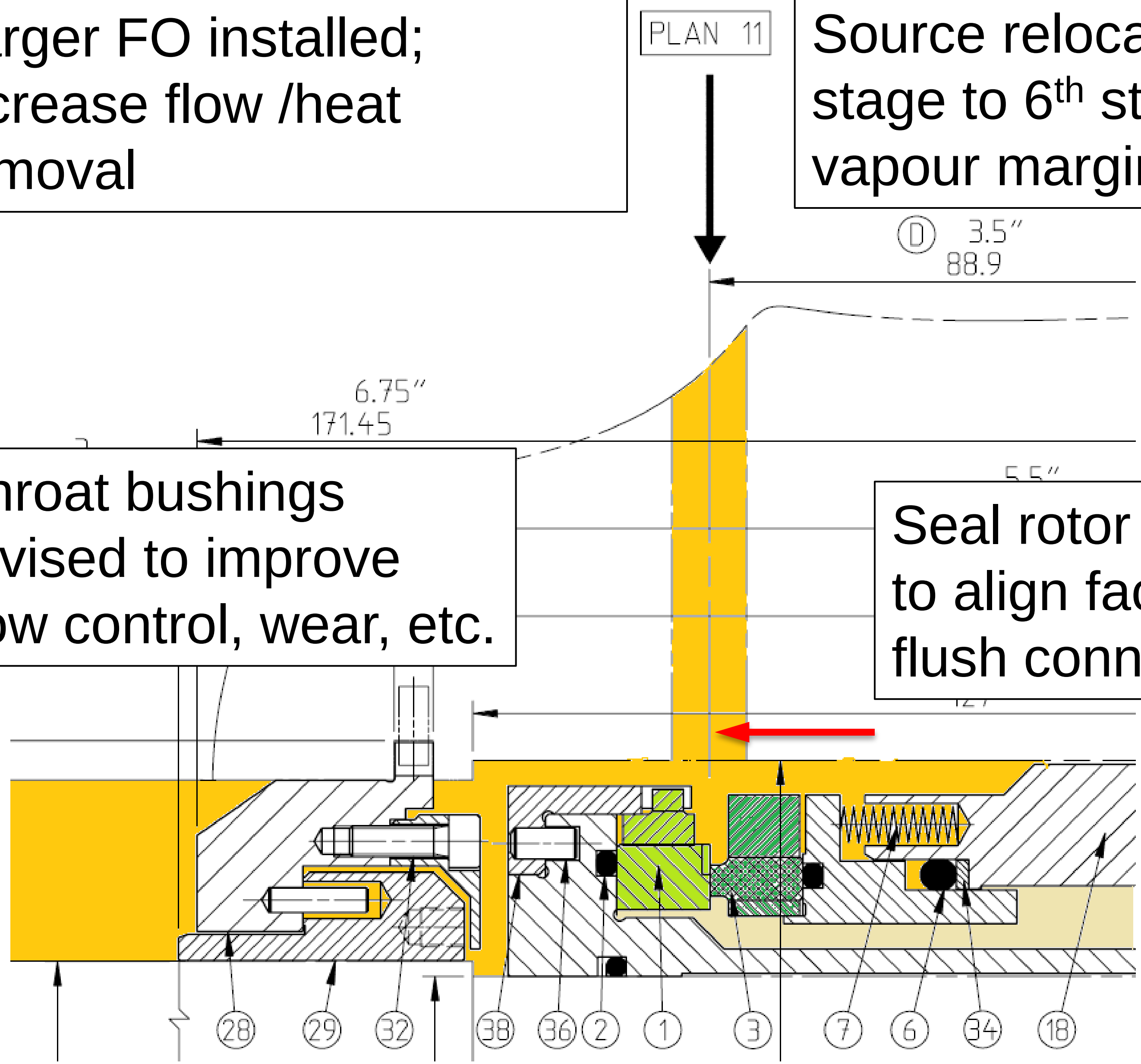
Plan 11 connection: incorrectly positioned – flush flow (cooling) not directly to seal faces



Typical operating case
July 30th 2011

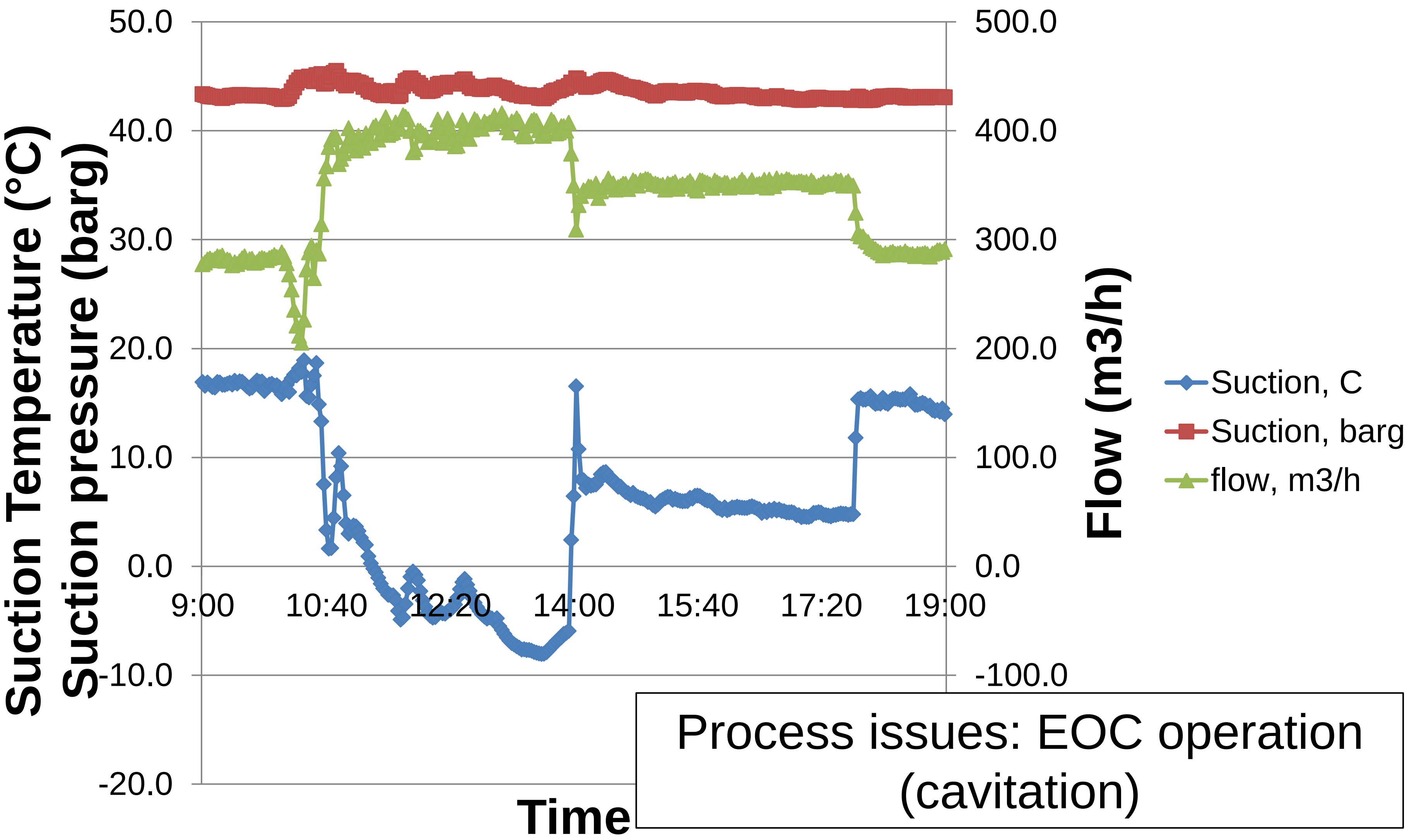
Larger FO installed; increase flow /heat removal

Source relocated from 1st stage to 6th stage; increase vapour margin at seal



Throat bushings revised to improve flow control, wear, etc.

Seal rotor redesigned to align faces with flush connection



Process issues: EOC operation (cavitation)

Example: pump operating conditions
July 30th 2011

Further measures taken in attempts to improve vapour margin included:

- Alternative floating throat bush; carbon and PEEK materials
- Moving plan 11 source from 1st stage discharge (7.5bar dP) to crossover; 6th stage discharge (45bar dP)

Result:

- Seal chamber pressure 63 barg (+18 bar); API minimum vapour margin ensured

MTBF remained unacceptable

Results

Seal life: increased from as little as 1 day to < 4 weeks

Result; greater consistency in seal life, but no significant improvement

Symptoms remained similar:

- Plan 76 pressure pulsations from first start
- Increasingly frequent till in permanent alarm
- Icing of plan 76 lines

Typical ‘dry running’ symptom

Process side silicon carbide seat, highly polished, worn and wavy

Result: increased wear rate of carbon stationary seal face

Investigation

Similar 2CW-CS, plan 11, 76, engineered seals were giving satisfactory performance in similar, related, pipeline services

- Smaller machines; lower shaft power, lower p.v. factor
  - API minimum vapour margins suitable for high power applications?

Pumps: one operating, one standby usually on open discharge relying on NRV to prevent spillback

- Low speed turning due to valve passing
  - Contributing factor but not primary
- Instances of pump cavitation

Conclusions

- Pump and seal duty points (shaft power, suction vapour margin, seal p.v.) are too high to permit creation of an appropriate degree of seal chamber vapour margin for a ‘wet’ primary seal
- Cooling process to seal to increase vapour margin is not viable; process temperature, CAPEX required, time, etc.

Recommendations

1. Allow process to vapourise in seal chamber and utilise a ‘gas’, non-contacting seal; 2CW-CS to 2NC-CS

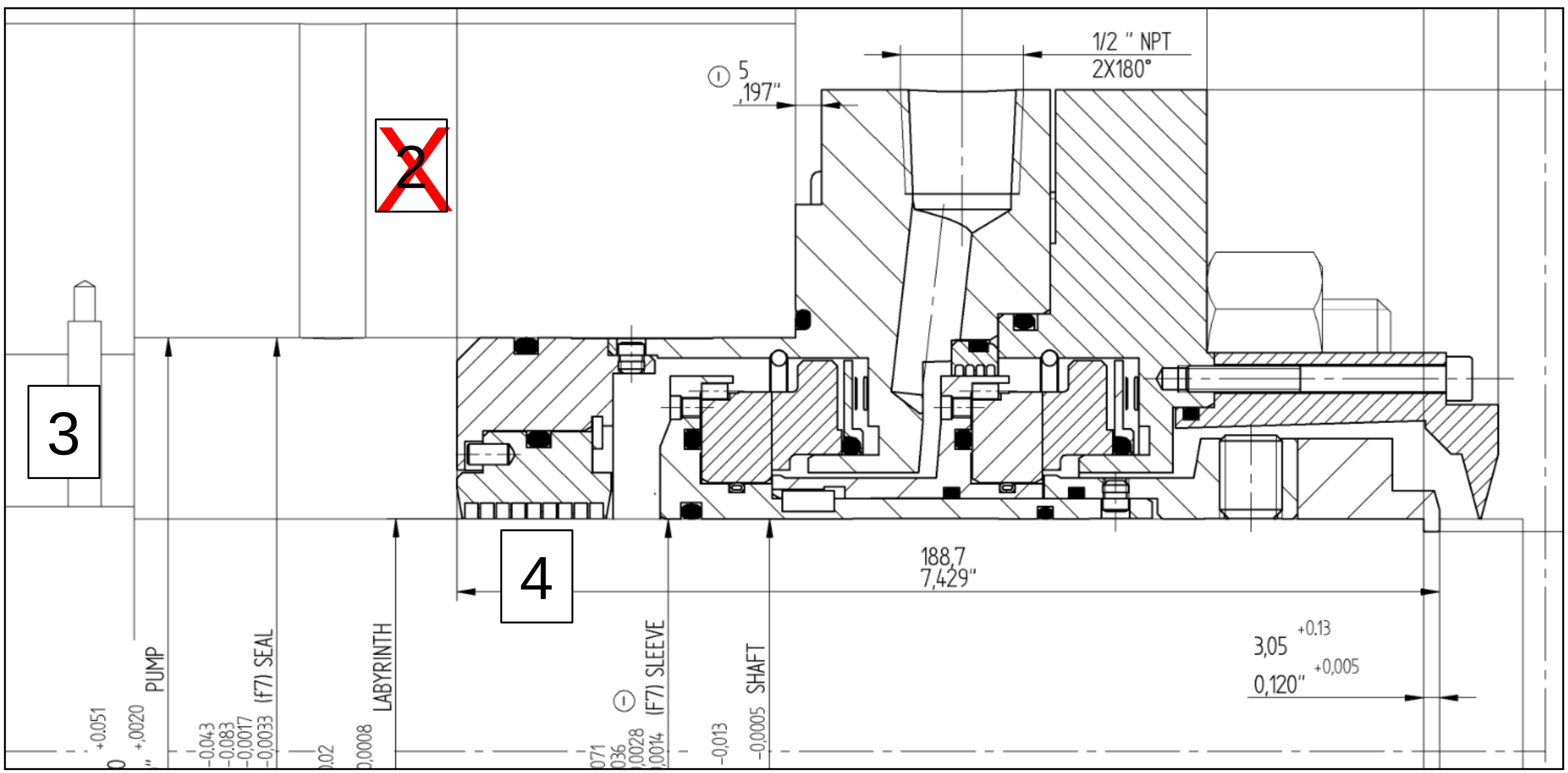
2. To minimise the normal static leakage of a gas seal solution use low friction face materials to permit seal start in full contact mode

Solution

Early 2011 programme to develop 2NC-CS ‘Gas’, vapour phase seals

Solution

1. Compressor DGS taken as basis for design
2. Plan 02 for primary seal (plan 11 plugged) to minimise face cooling / retain seal generated heat
3. Throat bushing opened / removed
4. Process labyrinth to retain seal heat at seal



Seal face features:

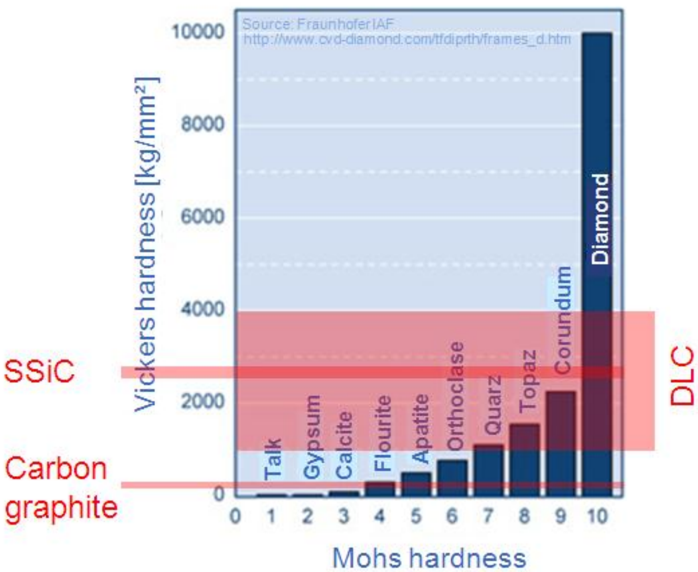
Minimise Joule Thomson cooling effects = minimise leakage rate, particularly static; target nil

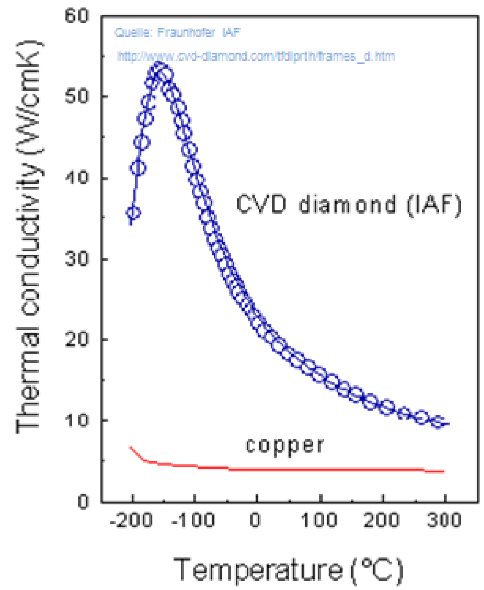
Hybrid design required; contacting (static) / lift off (dynamic), requires low friction faces

Diamond face (DF) coating providing wear resistance, low friction, high heat conductivity

face friction coefficients		
	SiC / SiC	SiC-DF/SiC-DF
Dry running	0,70	0,15
Liquid lubricated	0,08	0,01

Diamond properties





Cross section prepared by
Focused Ion Beam (FIB) cutting

- ✓ Extreme hardness, excellent wear resistance
- ✓ High thermal conductivity
- ✓ Chemical bonding => Superior diamond film adhesion

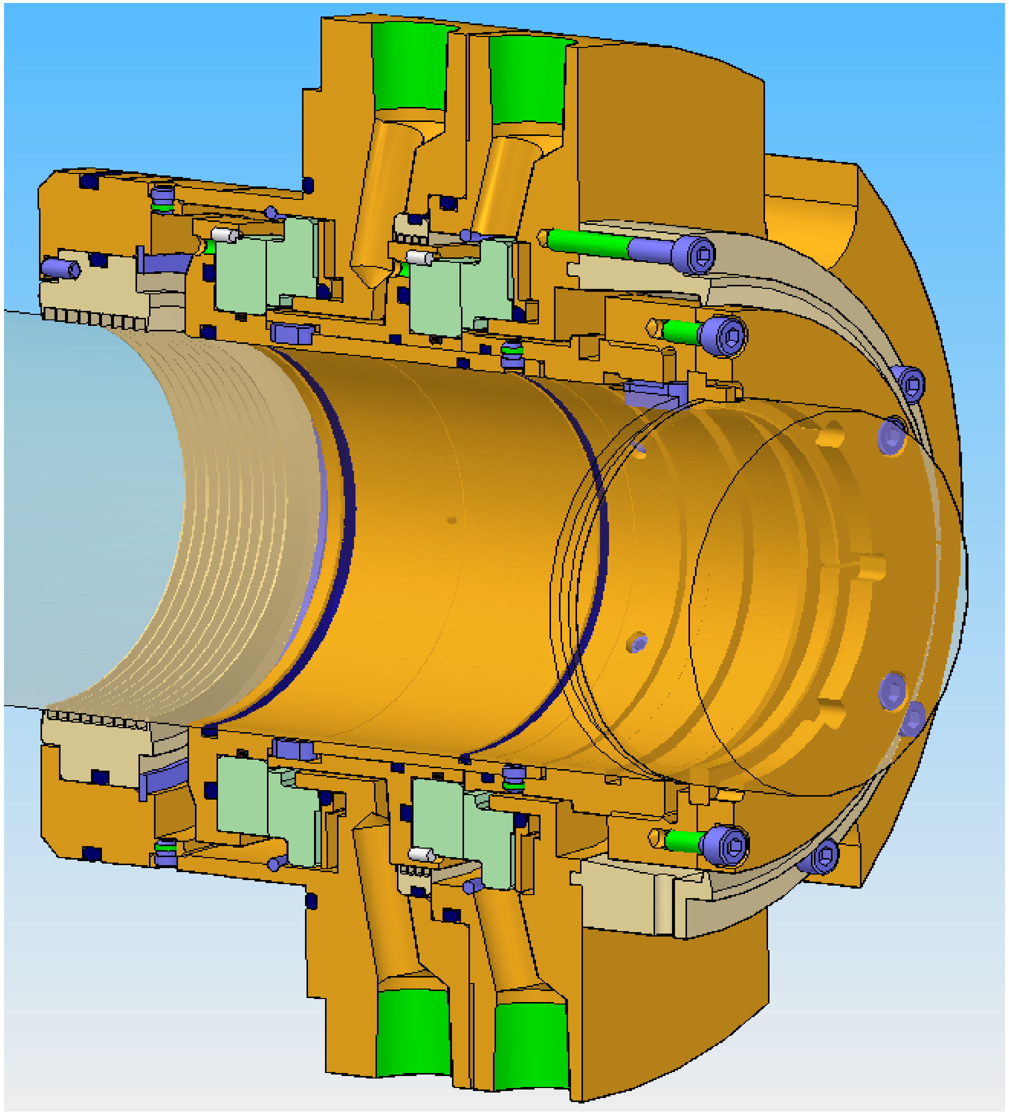
2NC-CS with:

- Process labyrinth
- Inter-stage labyrinth

Plan 02, 76 (optional 72)

Expected leak rates DF DGS (conventional DGS)

Dynamic: 2.7 (19) Nl/min
Static: nil



Primary seal dynamic leak rate on test: 2.5-2.8 Nl/min

Results

First pump converted: July 2011
Second pump: November 2011

Observations

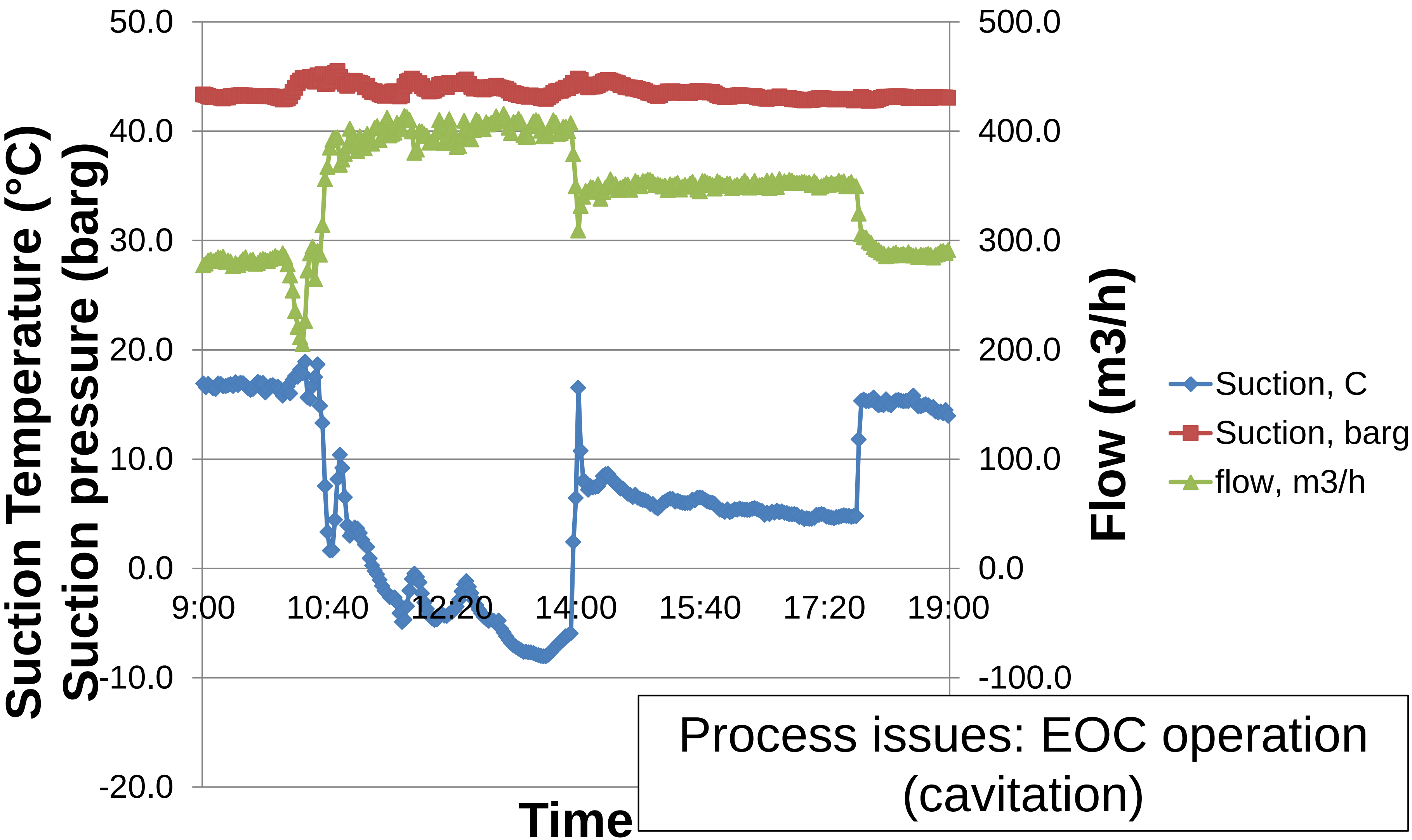
- Plan 76 pressure fluctuations no longer evident
  - on switch over or plant start
  - icing on plan 76 lines eliminated

Plant transients had no adverse effect on seal performance

- suction temperature to -8.3 °C
- EOC operation (cavitation)

Approx. 93% reduction in ethane emissions to flare

First pump de-staged in March 2012, seals inspected and returned to service in same machine, in service to date

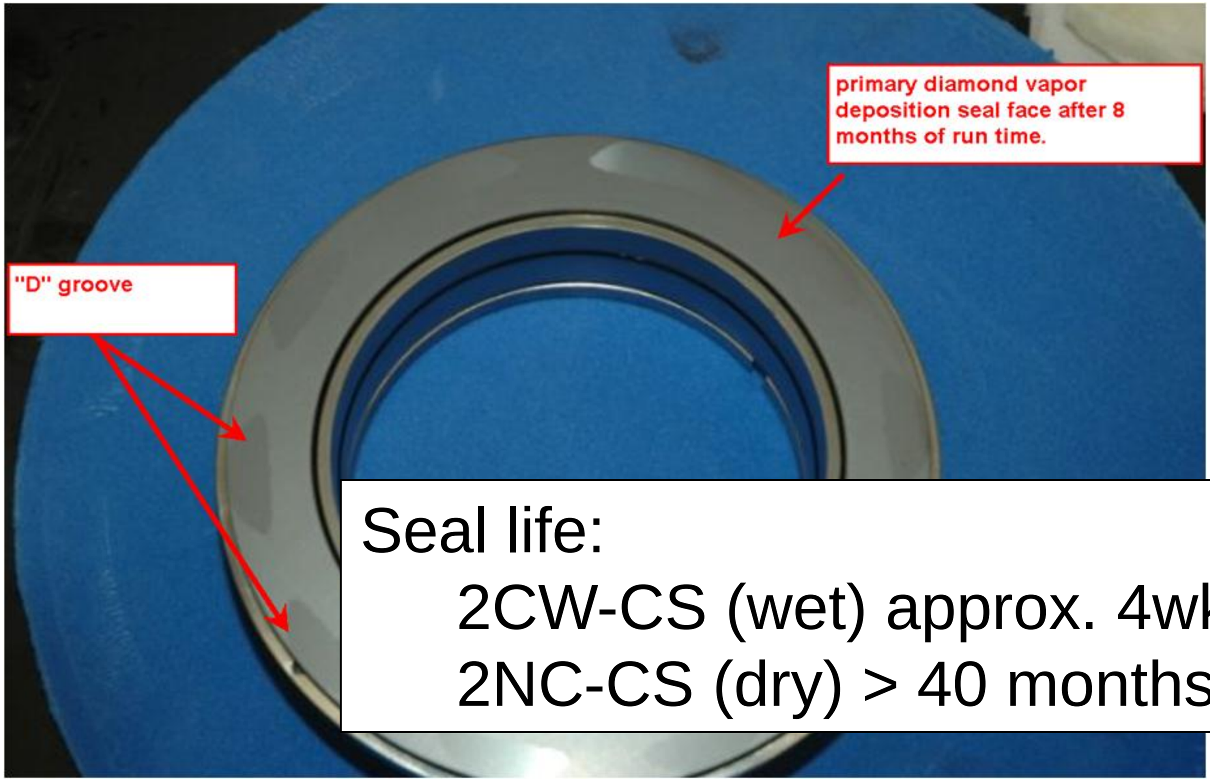


Example: pump operating conditions
July 30th 2011

March 2012 inspection (+8 months)

Seals from first machine inspected whilst machine was de-staged from 12 to 11 stages

Secondary sealing elements replaced, all other parts reused without any reconditioning. Test dynamic leakage rate: < 2 Nl/min



Seal life:

- 2CW-CS (wet) approx. 4wks
- 2NC-CS (dry) > 40 months in service

Lessons learnt

For high shaft power, high seal p.v. factor applications

- Machine waste energy becomes significant
- Seal generated heat is significant

Impractical to attempt to reliably operate ‘wet’ seals (liquid phase) even at vapour margins in excess of API682

Permitting / promoting process medium to change to vapour and operating ‘gas’ seals is realistic and such solutions are tolerant of process transients

Experience

36 machines at this and related operator sites since equipped with diamond face 2NC-CS gas seals

1 installation related failure

For process plants: plans 02, 72 (nitrogen buffer), 76

> Plan 02 usually with a process bushing
> Plan 72 as it is available (1 SCFM / seal)

For pipelines: plans 12 (flush via filter), 76

> Plan 12 for pipeline debris; products of pipeline corrosion, liquid pooling, atmospheric transients, pigging, etc.

<u>Questions?</u>